

Monolithic Compliant Space Mechanisms Design Strategies

Completed Technology Project (2013 - 2017)



Project Introduction

New additive manufacturing technologies such as Direct Metal Laser Sintering and Electron Beam Melting now allow 3D printing of complex geometries. These processes build up a part layer by layer, instead of removing material from a large block as in traditional machining. Such processes are ideal for low quantity production. Using these technologies, assemblies can be simplified to one part in a monolithic (made from a single solid piece) design. Advantages of monolithic designs include simplicity, robustness, and lower cost. Compliant mechanisms derive their motion from the flexing of constituent members. This eliminates sliding contact in bearings and joints, which can greatly increase reliability, especially in space. Because compliant mechanisms do not rely on assembled joints, they are ideally suited to monolithic designs. Combining additive manufacturing techniques with compliant mechanism technology has the potential to greatly increase performance and reduce costs in space technology applications. Compliant mechanisms are often designed to be monolithic, and using 3D additive machining processes is a natural step in the development of compliant mechanism technology. Adapting compliant mechanism design strategies for monolithic space technology carries some unique challenges that must be addressed in order to take full advantage of the technology. In the context of additive manufacturing techniques, I will address two major challenges: vibration characteristics and large strain energy. Because compliant mechanisms are flexible, they often have low natural frequencies, making them subject to undesirable vibrations. By employing the pseudo-rigid-body model of compliant mechanisms in conjunction with finite element analysis, I believe we can find ways to optimize compliant space mechanisms for high natural frequencies without compromising the needed flexibility. As compliant mechanisms are actuated they act as springs, storing energy as the flexible members deflect. This results in a need for larger input forces to overcome the mechanism's internal stiffness. Large actuators add mass, complexity, and increased power consumption. Static balancing has been demonstrated to be effective in reducing the force required to actuate compliant mechanisms. Usually static balancing strategies require some assembly step to introduce a pre-load that compensates for energy added during actuation. Think of an architect's lamp and how the springs compensate for the weight of the lamp. Now realize that all those springs and links add complexity and expense. Finding strategies for pre-load introduction without departing from monolithic fabrication will be a major part of ensuring the feasibility of this technology. By exploiting compliant mechanisms in monolithic designs, we can eliminate much of that complexity. By developing design guidelines that adapt compliant mechanisms to the needs of space technology I hope to take advantage of new advances in additive metal manufacturing to achieve unprecedented performance and longer life. This research will directly impact Technology Area 12.3 (Mechanical Systems), but TA13.3 (Increased Reliability) and TA04.3 (Robot Manipulation) will also benefit.



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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

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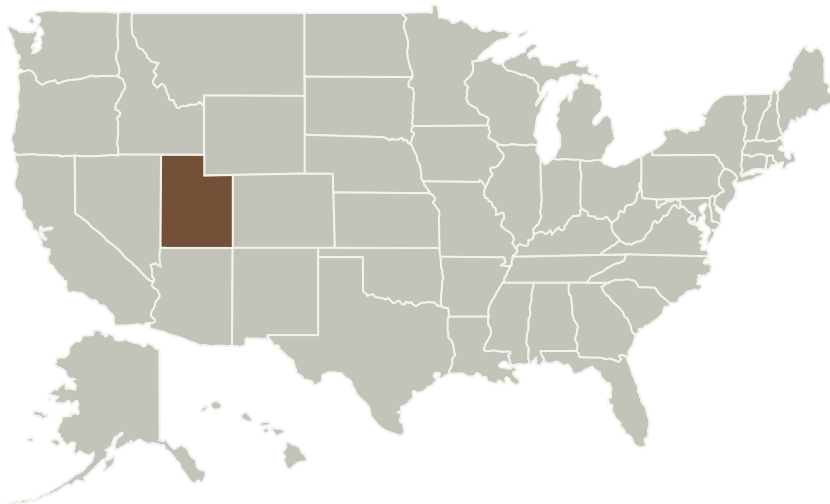
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Anticipated Benefits

By developing design guidelines that adapt compliant mechanisms to the needs of space technology the hope is to take advantage of new advances in additive metal manufacturing to achieve unprecedented performance and longer life. This research will directly impact Technology Area 12.3 (Mechanical Systems), but TA13.3 (Increased Reliability) and TA04.3 (Robot Manipulation) will also benefit.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Brigham Young University-Provo	Supporting Organization	Academia	Provo, Utah

Primary U.S. Work Locations

Utah

Project Website:

<https://www.nasa.gov/directorates/spacetech/home/index.html>

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

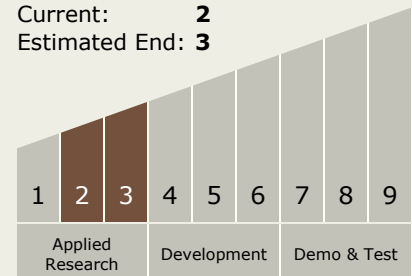
Larry Howell

Co-Investigator:

Ezekiel G Merriam

Technology Maturity (TRL)

Start: 2
Current: 2
Estimated End: 3



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
 - TX12.3 Mechanical Systems
 - TX12.3.3 Design and Analysis Tools and Methods